A Study of Pre-Earthquake Signatures from Ionospheric and Surface Parameters

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DECLARATION BY THE SCHOLAR

I hereby declare that the short synopsis in the area of **"A Study of Pre-Earthquake Signatures from Ionospheric and Surface Parameters"** being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in the department of Physics under Faculty of Applied Sciences of Manav Rachna University, Faridabad during the academic year 2021-2022.

It is the work that is expected to be carried out under the supervision of **Prof. Dinesh Kumar Sharma** and co-supervision **of Dr. Ananna Bardhan and Dr. Raj Kumari.** Further, it is certified that short synopsis is within the plagiarism limit and the copy of the same is attached as per University norms.

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ABSTRACT

Seismic activity causes a variety of Precursory Signatures to be seen over the ocean-land-atmosphere system. Earthquakes do significant destruction to both people and property. To research the precursory sign for early warning and prediction of earthquakes, different geophysical factors must be understood and monitored. The Surface thermal parameters are used to investigate the pre-earthquake surface and ionospheric abnormalities in this work - Surface latent heat flux (SLHF), Surface temperatures (ST) and ionospheric factors like ion density, ion plasma perturbation has been analyzed for the recent high magnitude earthquake. This study shows the anomalous behavior of ocean-land-atmosphere parameters before the most significant earthquakes. Before and during the earthquake, inconsistent variations in SLHF, ST and ionospheric parameters were observed throughout the surrounding land and oceanic regions (Dey et al., 2004). The earthquake information has been retrieved from the United States Geological Survey (USGS) (http://earthquake.usgs.gov/activity/world.html). Data on surface latent heat flux (SLHF) has been obtained from the National Center for Environmental Prediction (NCEP) (http://iridl.ldeo.columbia.edu/). The surface latent heat was analyses using the Climatological Analysis for Seismic Precursor Identification (CAPRI) algorithm (Piscini et al., 2017). Prior to the seismic activity, there was a major variation in surface latent heat flux. We will be analyzing the pre-earthquake early warning signature 2 months prior to the main earthquake activity.

Key words: Seismic Activity, Precursor, Surface Temperature, Surface Latent Heat Flux, Ionospheric parameters

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1. Introduction

Seismology's ultimate objective is to predict earthquakes. However, the analysis of probable seismic event signs must be seen more from the perspective of fundamental geophysics than in predicting an outcome (Ouzounov et al., 2018; Hough, 2020). An occurrence of the shaking is the end result of a continuing manner that happens in the earth's lithosphere as a result of plate tectonics constant conflict. When a fault extends to a critical distortion, it can no longer justify, it disintegrates, releasing the whole of the potential energy that has built up over decades, or even centuries (Scholz, 2002). Even though it is generally understood how the ground relates to the atmosphere during an earthquake (Tanimoto et al. 2015), what happens far before the earthquake is less well studied and strongly questioned. Several authors have considered information and lots of papers have been published claiming the space-time correlation observations - carefully taken as attainable seismic signatures and suggesting the strategies and procedures aimed toward predicting earthquakes. The earthquake precursors studied so far represent a wide range of physical factors starting by mechanical deformation to gas releases; from changes in groundwater levels to changes in the magnetic field associated with them; changes in ground temperature due to fluctuations in ionospheric and magnetosphere factors. The earliest findings of an association between approaching quakes and electromagnetic emanations were published date back to (James, 1982 ; Varotsos, 1981, Gokhberg et al. 1982). Approximately 50 years past, the success short-range forecasting of the strongest Haicheng (China) seismic activity and the disaster to forecast the event of Tangshan (China) (Lomnitz,1994)–despite its similar magnitude– opened a pivoting a tidal wave of optimism and delusions about one's chances of success forecasting seismic occurrences (Arvind Kumar et al., 2009; Seiya Uyeda et al., 2009). Unfortunately, just a few of these were reproduced during subsequent earthquakes (Davidenko & Pulinets, 2019; Hattori et al., 2013; Liu et al., 2010). As a result, findings from one of these are usually "unique" and distributed across the field of earthquake precursor investigations. Some initial findings, for example, showed that the area of interest might produce and distribute detectable electromagnetic signals across a wide range of frequencies prior to major earthquakes. The recent earthquake of 26 January 2001 in Bhuj, Gujarat showed substantial variations in the land (Singh et al., 2001a, b) and ocean parameters (Singh

et al., 2002,2001c). We've been studying the ground and atmospheric effects of factors near the ocean related to earthquakes. The study of multi-sensor results indicated unusual water vapor action in the environment earlier to Gujarat and further quakes, particularly those which took place close to the ocean and also had focal depths of up to 33 kilometers (Dey & Singh, 2003). Since earthquake prediction remains a difficult undertaking, researchers have reported that a number of geophysical parameters are strongly related to seismic activity (Knopoff, 1996). Many pre-earthquake ionospheric and geophysical factors have been related to quakes that have happened everywhere in the globe (Biagi, Piccolo, Ermini, Fujinawa, et al., 2001; Biagi, Piccolo, Ermini, Martellucci, et al., 2001; Merzer & Klemperer, 1997; Molchanov et al., 2001; Ohta et al., 2001; S. Uyeda et al., 2001; Hayakawa and Fujinawa, 1994; Hayakawa, 1999). If we study the types of these variables, we may be able to identify possible earthquake precursors. Many destructive earthquakes have happened near the ocean in the last few years (http://earthquake.usgs.gov/activity/world.html). According to the lithosphere–atmosphere–ionosphere coupling (LAIC) model (S. Pulinets & Ouzounov, 2011), during the earthquake preparatory phase, because of some flow of energy or particles from the lithosphere to the atmosphere and subsequently, to the ionosphere, a variety of precursory events occur. The methodology is based on an extensive study of numerous atmospheric and environmental variables whose anomalous changes have been related to forthcoming earthquakes. The major observations included TIR (thermal infrared radiation), EM (electromagnetic) changes, electron density (Ne) ion/radon activity, temperature of the air, and the ionosphere's humidity (González-Zamora et al., 2015). Though the LAIC model is not that accurate, it still indicates a heat lower-atmosphere infrared emission that will be observable to satellite sensors from space. From a few days to 2 months before an earthquake is a substantial fault, thermal abnormalities are seen above it, and they can extend up to a week thereafter. The anomaly is hundreds of kilometers in length and tens of kilometers in depth. Only a few processes can explain the anomaly. Heat transfer fluid is dissolved into water and gas nearby the surface, several kilometers below the surface, based on the seismic and geophysical structure. As a condition of the increased precursor tectonic stress that would probably result in the major fault displacement, gas, evaporating water, and heat reaching the surface of Earth via geological structures (faults, cracks, fractures, and so on). Changes in surface temperature affect soil humidity and, as a result, change the physical

characteristics of the soil, which interact with charged and neutral particles in the earth's atmosphere. Also, the greenhouse influence produced by optically active gases escaping from the lithosphere, may cause temperatures to increase (Harrison et al., 2014). S. Pulinets & Ouzounov (2011), the air temperature rises because of latent heat discharge from the liquid-vapor concentration of created ions by radon ionization of the air. Another important factor is that relative humidity decreases when the air temperature rises, which is not caused by greenhouse gas activity in most significant earthquakes. Several researchers have used satellite remote sensing data to investigate earthquake-related thermal abnormalities (Qiang et al. 1991; Aliano et al., 2008; Gorny et al. 1988), covers various seismic zones entirely throughout the world, including Middle Asia (Tronin 1996), the USA (Ouzounov & Freund, 2004), India (Blackett et al., 2011), Italy (Tramutoli et al. 2001; Qin et al. 2012; Piroddi et al. 2014), North Africa (Saraf and Choudhury 2005), etc. Recent research on thermal seismic precursors has focused on abnormal surface latent heat flux (Cervone et al., 2005; Dey & Singh, 2003; Qin et al., 2009), microwaves (Takashi and Tadashi 2010), and outward long-wave emission (Ouzounov et al. 2007). Akselevich and Tertyshnikov (1995) proposed studying the total amount of ozone in the atmosphere as a stratospheric seismic activity predictor. Tronin (2002) has reported on several examples of ozone concentration variations observed using a spectrometer for total ozone monitoring. The change in the water vapor concentration might be seen as a predictor of the quake preparation stage since it’s increased concentration is observed as a result of fluids rising and evaporating due to heat fluxAfter the 2001 M7.8 Gujarat earthquake, Dey et al. (2004) discovered a change in the total amount of water in the column. Ma et al. (2010) discovered significant water vapor anomalies before and following the Hengchun, Taiwan earthquake of 2006 (M7.2). Wu et al. (2016) observed several simultaneous abnormalities in various climatological variables before the 2009 M6.2 L'Aquila quake. The study of a considerable time series of thermal images in reference to a seismic risk is stimulated by natural occurrences and the availability of data. However, full satellite data processing is a difficult task: for example, infrared absorption by dense clouds prevents satellite thermal sensors from obtaining continuous surface temperature data, which might cause any thermal surface to lose abnormalities that occur before to seismic. To resolve this concern, we consider re-evaluation of climatological variables that combine a range of meteorological systems with statistical integration

techniques to provide prolonged and geographically continuing accurate datasets with substantial benefits over data obtained directly from satellite observations. Piscini et al. (2017) exposed three climatological parameters: skin temperature, total column water vapor, and the total column of Ozone, from European Center Medium Weather Forecast (ECMWF) reanalysis data in 37 previous years, and examine certain statistical parameters to those emerging from a suitably long duration (about 2 months i.e. 60 days) the outcome of 2016 Central Italy (Amatrice–Norcia) seismic series. This is due to the fact that we are very interested in what occurred before this seismic series in order to evaluate potential signs.

Various Precursory Signatures are observed over-land-atmosphere due to seismic activities. Therefore, the understanding and monitoring of various geophysical parameters are required to study the precursory signature for the early warning and the prediction of the earthquake. Some Precursor of Earthquake at the Surface,Atmosphere and Ionospheric level:

1. The Surface level Parameters (Surface Latent Heat Flux and Surface Temperature)
2. Gases that emerge from the earth and reach the surface
3. Electromagnetic Deviations
4. Ground Water level
5. Radon/Ion activity
6. Ionospheric Plasma Perturbation

Out of these, we will focus on the surface-level parameters. The Surface temperature(ST) and Surface latent heat flux (SLHF) and ionospheric factors in our study. This is due to the fact that we are predominantly interested in whatever occurred before this seismic event in order to analyze probable signs.

2. Literature Review

Seismicity is the extreme broadly researched phenomenology proceeding, throughout, and post-earthquakes (De Santis et al., 2019; Mignan, 2008). Furthermore, excessive low-frequency auditory emanations have been reported (Ihmlé & Jordan, 1994) represent seismic activity signs earlier the major earthquake on a greater frequency. Mechanical distortions in the lithospheric layer, such as those detected by slip and stain patterns (Langbein, 2015; Niu

et al., 2008). Temperature fluctuations have been related to earthquakes previously, and they might be explained by changes in the movement of groundwater and rising temperatures, or more recently, condensation of vapor on the surface (Tramutoli et al., 2005). Gas exhalations of gases, mostly radon or radioactive ions, are caused by gas-water emissions into the atmosphere from earthquake preparation regions (S. A. Pulinets et al., 2003). Variation in groundwater level and composition has been observed over a few weeks, up to and about to a few hours earlier seismic activity (M. Hayakawa et al., 1997; Koizumi et al., 1999). As an earthquake precursor, surface latent heat flux, tried understanding the background noise level in the epicentral zones of five earthquakes under consideration in this research. The rise of SLHF was directly associated with the season in which the earthquake occurred; the biggest and lowest abnormalities occurred in the summer and winter, respectively. The epicenters and the surrounding region's considerable surface and groundwater can generate the required conditions for SLHF to occur. More earthquake cases are required to investigate its physical mechanism in greater depth (Qin et al., 2009).The research work focuses mainly on the occurrence of the surface and ionospheric abnormalities before the Sendai earthquake event, as well as the importance of combining multi-source data in finding seismo-precursors. They don’t want to go in detail on the physical process of lithosphere–atmosphere–ionosphere interaction. It should also be noted that on March 9, 2011, an M7.2 earthquake occurred around 40 kilometers distant from the M9.0 quake. The anomaly in SLHF and TEC might have sign to the M7.2 earthquake. They don't focus strongly on this (Xu et al., 2011).A Researcher focusing on Earthquakes prior to the Papua, Haiti, Samoa and South Sandwich Islands seismic activity have comparatively low amplitude and are challenging to consider as precursory changes. The bulk of the abnormalities that occurred before all six seismic activities really aren't time-related to an earthquake in any of the studied areas. To eliminate subjectivity, we suggest that anomaly-identifying procedures based on long-term regional research be developed before adopting SLHF data for earthquake prediction. Other factors that might produce SLHF variations should be thoroughly examined as well (Yao et al., 2013) . It was determined that the SLHF's anomalous behavior before the major earthquake is mainly related to the coastal earthquake after a study of SLHF from epicentral locations above coastal seismic events and earthquakes distant away from the coast (Dey & Singh, 2003).The earthquake of Gujarat indicates that a water vapor abnormality is observed across

the land region earlier the seismic activity. The distribution of significant levels of water vapor in the epicentral area decreases after the main event. Water vapor over the ocean may be caused by sudden surface and subsurface distortions in the epicentral area of an earthquake. To investigate its close relationship with any earthquake, detailed analyses of water vapor in the atmosphere concentration as well as its temporal variations of earthquakes, both before and after are necessary (Dey et al., 2004). The unusual SLHF and midnight LF sub-ionospheric emissions are discovered to be related to the major Tokachi-Oki earthquake on September 25, 2003. The comparable nature of the characteristics may prove useful in giving information about an impending disaster upcoming quake (Cervone et al., 2006). Acoustic gravity waves (AGW) propagation (Molchanov and Hayakawa, 2008); recently, a seismo-ionospheric physical mechanism interaction that includes AGW, as well as radon emanation, have both been proposed (Rapoport et al., 2020). Electric and magnetic field components fluctuate across a large frequency range from ULF to VHF [Liang et al., 2015; Seiya Uyeda et al., 2009] (Sorokin et al., 2020). Various explanations of electromagnetic emissions focused on earthquake location or measure together with the corresponding line of the field or scattered surrounding on the ground and in space, it has been reported. Observations of ionospheric variables from the ground [Total Electron Content (TEC) (Liu et al., 2004, 2010), critical frequency foF2 (Hobara & Parrot, 2005), VLF reflection height (M. Hayakawa et al., 1997; Masashi Hayakawa et al., 1996; Rodger et al., 1999)].The Wenchuan seismic data of multi-parameter and found considerable changes in these parameters before to the event's occurrence (Jing et al., 2013). Skin temperature, total column vapor, and total column ozone were measured two months before the Amatrice–Norcia (Central Italy) seismic series and compared to the prior 37-year trend. On the 26th of October, an M5.9 occurred, and on the 30th of October, an M6.5 occurred. An Italian study has shown that the behavior of earthquakes can be used as a useful resource in an integrated system for earthquake prediction in the future (Piscini et al., 2017). Pre-earthquake ionospheric abnormalities occur between 18:00 – 22:00 LT within five days before 16/20 M≥6.0 seismic activity. This 80% success rate shows that the GPS TEC is helpful for detecting pre-earthquake ionospheric abnormalities that manifest earlier major earthquakes (Tariq et al., 2019). The appearance of thermal anomalies, which often precede stratovolcano/caldera eruptions, appears to occur several days following SO2 emanations. The meteorological

abnormalities that occur before volcanic eruptions at high latitudes typically encircle the volcano and extend beyond the volcanic edifice. They are the first to show that climate data can be predicted ahead of time, with accuracy ranging from 91 to 100 percent (Piscini et al., 2019). The Researcher has been studying the background noise inside the epicentral zones of the ten quakes that have struck the Indian Subcontinent in the previous 42 years. They found that the abnormal activities of SLHF before the main trembling occurrences were very slightly related to coastal earthquake activity. The longitudinal and latitudinal impacts of the SLHF anomaly were explored for 10 earthquakes throughout the Indian subcontinent (Adarsh Kumar, 2020).

Research Gap: So far, the early warning system hasn't been shown to be completely reliable in the event of an earthquake. Earthquake prediction is a difficult challenge for us, and we need to put in a lot of work to figure out how to acquire seismic precursor data. Different earthquake monitoring systems, extensive remarks both from space and from the ground, will be critical in the future. It is still detectable in tsunamis etc., since sea level varies, but it is not highly predictable over land. As a result, more study in this area is required.

3. Description of Topic

Earthquake Preparation Region

Several scholars invented the seismic preparation zone concept (Bowman et al., 1998; Dobrovolsky et al., 1979; Keilis-Borok & Kossobokov, 1990). The region where local deformations are recorded in the initial level is known as the earthquake preparation zone. The crustal structure and shape change as a result of this deformation, which is studied using various techniques. As per dilatation theory, faults occurring in the preparation zone are often followed by a change in electrical resistivity, geochemical processes, density, an increase in seismic wave velocity, and groundwater elevation (Scholz et al., 1973). Experimentally, prior indications can be recorded. All of the chemical and physical abnormalities discovered in the seismic preparation zone act as a base for earthquake prediction.

The following calculation may be used to determine the preparation zone's size:

$$\rho = 10^{0.43M}\ \text{km}$$

where M is the quake's magnitude (Dobrovolsky et al., 1979). However, only by exact measurements can the size of the seismic preparation region be estimated. For the precise and accurate prediction of the earthquake preparation zone, several factors such as a focal mechanism, tectonic plate faults, and differences in the geographic structure are taken into account. Along with the crustal deformation, a number of precursory signs are considered as being implicated in a future earthquake. In the earthquake preparation zone, different gases are discharged from the Earth's crust. Radon and carbon dioxide are two important gases that are emitted. Radon gas ionizes the air nearby the surface of the earth in the existence of an abnormal electric field. The CO2 gas carries numerous metallic particles, which increases the ion concentration even further. As a result, metallic aerosols vary the electric field in the lower atmosphere. In the volatile form, they include Sb, As, and Hg. All of these geochemical events have been recorded in the seismic preparedness zone. An unusual vertical electric field is another major precursor connected with earthquakes. A few hours or days before an earthquake, an anomalous vertical electric field is found. The basis for seismo-ionospheric coupling is all of these physical and chemical processes.

The Mechanism of Seismo-Ionospheric Coupling

Throughout the earthquake preparation phase, different geochemical activities such as the release of radon and other gases are seen in terms of mechanical deformations. These gases ionize the lower atmosphere much more. The ionization of the atmosphere near the ground affects the Earth's vertical electric field. The "electrode effect" describes this phenomenon. When the Earth prepares for an earthquake, radon gas ionization causes the generation of plasma in the lower atmosphere. The ions generated in this process react with water molecules near the Earth's surface; forming long-lived ion clusters. The ions generated during this duration cannot recombine due to the high dipole of water molecules. The mobility of positive and negative plasma particles differs, which aids in charge separation. Coulomb attraction causes the ion clusters to form quasineutral clusters. During the earthquake preparation stage, the atmosphere near the ground surface becomes rich in ion clusters and is covered with neutrals. In the seismo-ionospheric coupling process, this is the

first phase. In the second stage of this coupling process, an abnormal electric field is formed. Gas emission has a dual purpose. For starts, it causes the formation of ion clusters. Second, it causes the air near the ground to move. These air movements disintegrate the neutral clusters that surround the ions. As a result, the ion concentration at the ground surface rises sharply in a very limited duration of time. This resulted in the formation of an abnormal vertical electric field. Under normal conditions, the vertical electric field is roughly 100V/m, but it rises abnormally to around 1 kV/m during the earthquake preparation period, with a span from peak-to-peak of more than 1.5kV/m. Many geomorphological or geophysical elements influence the direction of the produced anomalous electric field, whether upward or downward. Metallic aerosols are sometimes seen in combination with gases emitted before an earthquake. The metallic aerosols increased the magnitude of the anomalous electric field. Latent processes occur in the Water molecules interacting with the vertical electric field and the water vapor balance produce an earthquake preparation zone. This alters the latent heat flow much further. Ionospheric precursors are linked to latent heat flux, abnormal electric fields, and water vapors created before an earthquake, either directly or indirectly. In the earthquake preparation zone, all of these precursors are seen almost simultaneously. The abnormal electric field produced by an earthquake enters the E area. This electric field causes both negative and positive anomalies in the E area. Whether the electric field area is extended or circular determines the shape and size of the irregularity. The electric component perpendicular to Earth's magnetic field lines, on the other, can only penetrate the ionosphere. If the anomalous vertical electric field is directed downward, the sporadic E layer forms over the research area. The abnormal electric field reaches the ionosphere at greater altitudes without dissipating along with the Earth's equipotential magnetic field lines. There are generally two types of precursory indications seen in the F area of the ionosphere. First, small-scale density anomalies are first discovered as a result of Joule heating's acoustic gravity waves. Second, there are large-scale electron and ion density abnormalities in the F2 area. A network of GPS receivers and satellites detects these abnormalities. The large-scale F2 area abnormalities and the small-scale irregularities caused by acoustic gravity waves shift from the usual location to the equator due to the difficulty of the particle drift process.

4. Objectives of Research

1) To investigate the abnormal behavior of Surface Latent Heat Flux (SLHF) earlier the major seismic activity.
2) To investigate how the temperature of the earth's surface variations during earthquake activity.
3) To investigate the abnormal behavior of the ionospheric precursor.

Every year, a great number of earthquakes occur all around the world. Out of them almost hundreds are having the magnitude greater than 5.They damage the huge life and property loss on the globe are the cause of earthquake activities. Therefore, the effect of seismic activity in terms of precursors is the most important challenge of the present day. The main purpose of the research would be to carry out a detailed analysis of the pre-earthquake precursor and data collected from various places. The aim of these measures is to determine the signature of the earthquake precursory as an early warning produced by earthquakes and the impacts on human mortality among individuals who live in or near the region. The data will also determine the abnormalities in this region of the continent where earthquakes are more likely to occur.

5. Seismic Data sources and Methodology

Natural disasters, especially earthquakes, create havoc on humanity. The average person expects technology to develop in such a manner that the extent of protection increases. Seismic preparation is a physiological process, but ours faults show our inability to understand its fundamental nature. The Earth begins to prepare itself days before a giant earthquake, with ionospheric precursors seen over the duration. A more statistical and analytical study is required to have a strong knowledge of it. As a result, earthquake event data The United States Geological Survey (USGS) provided information from (NEIC-National Earthquake Information Centre, www.earthquake.usgs.gov). Surface Latent Heat Flux (SLHF) data from the National Center for Environmental Prediction (NCEP), (http://iridl.ldeo.columbia.edu/) (Dey & Singh, 2003) were collected over a pixel spanning the epicenter of earthquakes and data was collected from the National Centre for Atmospheric Research Scientific Computing Division (http://ingrid.ldeo.columbia.edu/SOURCES/NOAA/NCEP-NCAR/)(Dey & Singh, 2003).

NCEP maintains a worldwide database of numerous meteorological and surface data. This database includes using data from satellites as well as observed data from various geographic stations. Through an assimilation process, In-situ measurements are among the fluxes take into account by operational weather prediction models**.** The primary concern with the data source is substantial variations in the procedure proposed and model resolution, which NCEP's re-analysis technique has overcome by collecting the whole-recorded data set into an only fixed data integration system. Kalnay et al. (1996) presented the reliability and the detailed explanation of the NCEP Surface latent heat flux (SLHF) data reanalysis. The daily readings of SLHF were taken into account for two months before earthquakes (Yao et al., 2013). The analysis of the surface latent heat has been done through CAPRI i.e. Climatological Analysis for Seismic Precursor Identification is an algorithm that uses climatology to identify seismic precursors (Piscini et al., 2017). Miguel et al. (1982) satellite measurements of ionospheric precursors of earthquakes might have been related to the beginning of the 80th century. The following satellites were found to have ionospheric precursors: GEOS – 1 and 2 – 1978, GPS – 1994-2003, AE-C-1973 and SROSS-C2 Satellite, and so on. Many agencies have established infrastructure to investigate the ionospheric system and its influence on other natural atmospheric processes as well as various man-made activities. In ionosphere research, the Indian Space Research Organization (ISRO), the European Space Agency (ESA), and others are in the lead. The National Physical Laboratory (NPL) in New Delhi developed and implemented SROSS-C2 series of satellites Retarding Potential Analyzer (RPA). The data obtained from the Retarded Potential Analyzer (RPA) onboard the SROSS-C2 satellite under the Indian Space Research Organization (ISRO) program of scientific utilization of SROSS-C2 data. This satellite was launched on May 4, 1994, at 420×620 km altitude.

6. Expected outcomes of the research

Earthquake activities data will be downloaded from The United States Geological Survey (USGS) (NEIC-National Earthquake Information Center, www.earthquake.usgs.gov) of different locations. We will try to analyses the anomalous behavior as pre-earthquake precursors before and during the high magnitude earthquake activities from Surface

parameters (Surface Latent Heat Flux and Surface Temperature) and Ionospheric Parameters (Ion density, Ion Plasma).

7. References

Akselevich, V. I., & Tertyshnikov, A. V. (1995). Methodology of ecological monitoring data application to seismic forecasting. *ATMOSPHERIC AND OCEANIC OPTICS C/C OF OPTIKA ATMOSFERY I OKEANA*, *8*, 567-569.

Aliano, C., Corrado, R., Filizzola, C., Genzano, N., Pergola, N., & Tramutoli, V. (2008). Robust TIR satellite techniques for monitoring earthquake active regions: limits, main achievements and perspectives. *Annals of Geophysics*, *51*(1), 303-317.

Biagi, P. F., Piccolo, R., Ermini, A., Fujinawa, Y., Kingsley, S. P., Khatkevich, Y. M., & Gordeev, E. I. (2001). Hydrogeochemical precursors of strong earthquakes in Kamchatka: further analysis. *Natural Hazards and Earth System Sciences*, *1*(1/2), 9-14.

Biagi, P. F., Piccolo, R., Ermini, A., Martellucci, S., Bellecci, C., Hayakawa, M., ... & Kingsley, S. P. (2001). Possible earthquake precursors revealed by LF radio signals. *Natural Hazards and Earth System Sciences*, *1*(1/2), 99-104.

Bina, C. R. (1998). A note on latent heat release from disequilibrium phase transformations and deep seismogenesis. *Earth, planets and space*, *50*(11), 1029-1034.

Bowman, D. D., Ouillon, G., Sammis, C. G., Sornette, A., & Sornette, D. (1998). An observational test of the critical earthquake concept. *Journal of Geophysical Research: Solid Earth*, *103*(B10), 24359-24372.

Blackett, M., Wooster, M. J., & Malamud, B. D. (2011). Exploring land surface temperature earthquake precursors: A focus on the Gujarat (India) earthquake of 2001. *Geophysical Research Letters*, *38*(15).

Brohan, P., Kennedy, J. J., Harris, I., Tett, S. F. B., & Jones, P. (1850). Global temperature record. *uncertainty estimates in regional and global observed temperature changes: a new*

dataset from.

Cervone, G., Maekawa, S., Singh, R. P., Hayakawa, M., Kafatos, M., & Shvets, A. (2006). Surface latent heat flux and nighttime LF anomalies prior to the M w= 8.3 Tokachi-Oki earthquake. *Natural Hazards and Earth System Sciences*, *6*(1), 109-114.

Chiarabba, C., Amato, A., Anselmi, M., Baccheschi, P., Bianchi, I., Cattaneo, M., ... & Mele, F. (2009). MORE FAULTS, MORE EARTHQUAKES, MORE HAZARD? A CASE STUDY FROM ABRUZZI, CENTRAL ITALY.

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and psychological measurement*, *20*(1), 37-46.

González-Zamora, Á., Sánchez, N., Martínez-Fernández, J., Gumuzzio, Á., Piles, M., & Olmedo, E. (2015). Long-term SMOS soil moisture products: A comprehensive evaluation across scales and methods in the Duero Basin (Spain). *Physics and Chemistry of the Earth, Parts A/B/C*, *83*, 123-136.

Dobrovolsky, I. P., Zubkov, S. I., & Miachkin, V. I. (1979). Estimation of the size of earthquake preparation zones. *Pure and applied geophysics*, *117*(5), 1025-1044.

Davidenko, D. V., & Pulinets, S. A. (2019). Deterministic variability of the ionosphere on the eve of strong (M≥ 6) earthquakes in the regions of Greece and Italy according to long-term measurements data. *Geomagnetism and Aeronomy*, *59*(4), 493-508.

De Santis, A., Abbattista, C., Alfonsi, L., Amoruso, L., Campuzano, S. A., Carbone, M., ... & Santoro, F. (2019). Geosystemics view of Earthquakes. *Entropy*, *21*(4), 412.

Dey, S., Sarkar, S., & Singh, R. P. (2004). Anomalous changes in column water vapor after Gujarat earthquake. *Advances in Space Research*, *33*(3), 274-278.

Dey, S., & Singh, R. P. (2003). Surface latent heat flux as an earthquake precursor. *Natural Hazards and Earth System Sciences*, *3*(6), 749-755.

Dobrovolsky, I. P., Zubkov, S. I., & Miachkin, V. I. (1979). Estimation of the size of

earthquake preparation zones. *Pure and applied geophysics*, *117*(5), 1025-1044.

Freund, F. and Ouzounov, D.: EOS Trans. AGU, Fall Meet. Suppl. Abstract, 82(47), 2001.

Gokhberg, M. B., Morgounov, V. A., Yoshino, T., & Tomi-zawa, I. (1982). Determination of the Characteristics of Ionospheric Disturbance in the near Zone of the Earthquake Epicenter. *Journal of Geophysical Research*, *87*(B9), 7824-7828.

Gornyy, V. I., Tronin, A. A., Shilin, B. V., & Sal'man, A. G. (1988). Outgoing terrestrial infrared radiation as an indicator of seismic activity.

Han, P., Hattori, K., Hirokawa, M., Zhuang, J., Chen, C. H., Febriani, F., ... & Yoshida, S. (2014). Statistical analysis of ULF seismomagnetic phenomena at Kakioka, Japan, during 2001–2010. *Journal of Geophysical Research: Space Physics*, *119*(6), 4998-5011.

Harrison, R. G., Aplin, K. L., & Rycroft, M. J. (2014). Brief Communication: Earthquake–cloud coupling through the global atmospheric electric circuit. *Natural Hazards and Earth System Sciences*, *14*(4), 773-777.

Hattori, K., Han, P., Yoshino, C., Febriani, F., Yamaguchi, H., & Chen, C. H. (2013). Investigation of ULF seismo-magnetic phenomena in Kanto, Japan during 2000–2010: case studies and statistical studies. *Surveys in Geophysics*, *34*(3), 293-316.

Hayakawa, M., Yoshino, T., & Morgounov, V. A. (1993). On the possible influence of seismic activity on the propagation of magnetospheric whistlers at low latitudes. *Physics of the earth and planetary interiors*, *77*(1-2), 97-108.

Hayakawa, M., Kawate, R., Molchanov, O. A., & Yumoto, K. (1996). Results of ultra-low-frequency magnetic field measurements during the Guam earthquake of 8 August 1993. *Geophysical Research Letters*, *23*(3), 241-244.

Hayakawa, M., Molchanov, O. A., Ondoh, T., & Kawai, E. (1997, June). On the precursory signature of Kobe earthquake on VLF subionospheric signals. In *IEEE International Symposium on Electromagnetic Compatibility* (pp. 72-75). INSTITUTE OF ELECTRICAL ENGINEERS INC (IEEE).

Hayakawa, M. (Ed.). (1999). *Atmospheric and ionospheric electromagnetic phenomena associated with earthquakes*. Terra Scientific Publishing Company.

Hobara, Y., & Parrot, M. (2005). Ionospheric perturbations linked to a very powerful seismic event. *Journal of Atmospheric and Solar-Terrestrial Physics*, *67*(7), 677-685.

Hough, S. (2020). *The Great Quake Debate: The Crusader, the Skeptic, and the Rise of Modern Seismology*. University of Washington Press.

Ihmlé, P. F., & Jordan, T. H. (1994). Teleseismic search for slow precursors to large earthquakes. *Science*, *266*(5190), 1547-1551.

Jing, F., Shen, X. H., Kang, C. L., & Xiong, P. (2013). Variations of multi-parameter observations in atmosphere related to earthquake. *Natural Hazards and Earth System Sciences*, *13*(1), 27-33.

Kalnay, E., Kanamitsu, M., Kistler, R., et al.: Bull. Am. Meteorol. Soc., 77 (3), 437–471, 1996.

Keilis-Borok, V. I., & Kossobokov, V. G. (1990). Preliminary activation of seismic flow: Algorithm M8. *Phys. Earth and Planet. Inter*, *61*, 73-83.

Khilyuk, L. F., Robertson Jr, J. O., Endres, B., & Chilingarian, G. V. (2000). *Gas migration: events preceding earthquakes*. Elsevier.

Knopoff, L.: Earthquake prediction: The scientific challenge, Pro-ceeding of National Science, USA, 93, 3719–3720, 1996.

Koizumi, N., Tsukuda, E., Kamigaichi, O., Matsumoto, N., Takahashi, M., & Sato, T. (1999). Preseismic changes in groundwater level and volumetric strain associated with earthquake swarms off the east coast of the Izu Peninsula, Japan. *Geophysical research letters*, *26*(23), 3509-3512.

Kumar, A. (2020). Long term (1975-2016) anomaly of surface latent heat flux (SLHF) over Indian subcontinent: Signatures of early warning of earthquake disasters.

Langbein, J. (2015). Borehole strainmeter measurements spanning the 2014 Mw6. 0 South Napa Earthquake, California: The effect from instrument calibration. *Journal of Geophysical Research: Solid Earth*, *120*(10), 7190-7202.

Liu, J. Y., Chen, C. H., Chen, Y. I., Yang, W. H., Oyama, K. I., & Kuo, K. W. (2010). A statistical study of ionospheric earthquake precursors monitored by using equatorial ionization anomaly of GPS TEC in Taiwan during 2001–2007. *Journal of Asian Earth Sciences*, *39*(1-2), 76-80.

Liu, J. Y., Chuo, Y. J., Shan, S. J., Tsai, Y. B., Chen, Y. I., Pulinets, S. A., & Yu, S. B. (2004, April). Pre-earthquake ionospheric anomalies registered by continuous GPS TEC measurements. In *Annales Geophysicae* (Vol. 22, No. 5, pp. 1585-1593). Copernicus GmbH.

Lomnitz, C. (1994). *Fundamentals of earthquake prediction*. Wiley.

Ma, Y., Zhao, Y., Liu, S., & Wu, L. (2010). Possible abnormal phenomenon of the atmospheric water vapor before Hengchun earthquake. *PIERS Online*, *6*(1), 21-25.

Maeda, T., & Takano, T. (2009). Detection algorithm of earthquake-related rock failures from satellite-borne microwave radiometer data. *IEEE Transactions on geoscience and remote sensing*, *48*(4), 1768-1776.

Merzer, M. O. S. H. E., & Klemperer, S. L. (1997). Modeling low-frequency magnetic-field precursors to the Loma Prieta earthquake with a precursory increase in fault-zone conductivity. *Pure and Applied Geophysics*, *150*(2), 217-248.

Mignan, A. (2008). The stress accumulation model: Accelerating moment release and seismic hazard. *Advances in geophysics*, *49*, 67-201.

Molchanov, O., Kulchitsky, A., & Hayakawa, M. (2001). Inductive seismo-electromagnetic effect in relation to seismogenic ULF emission. *Natural Hazards and Earth System Sciences*, *1*(1/2), 61-67.

Molchanov, O. A., & Hayakawa, M. (2008). *Seismo-electromagnetics and related phenomena: History and latest results* (Vol. 189). Tokyo: Terrapub.

Niu, F., Silver, P. G., Daley, T. M., Cheng, X., & Majer, E. L. (2008). Preseismic velocity changes observed from active source monitoring at the Parkfield SAFOD drill site. *Nature*, *454*(7201), 204-208.

Ohta, K., Umeda, K., Watanabe, N., & Hayakawa, M. (2001). ULF/ELF emissions observed in Japan, possibly associated with the Chi-Chi earthquake in Taiwan. *Natural Hazards and Earth System Sciences*, *1*(1/2), 37-42.

Ouzounov, D., & Freund, F. (2004). Mid-infrared emission prior to strong earthquakes analyzed by remote sensing data. *Advances in space research*, *33*(3), 268-273.

Ouzounov, D., Liu, D., Chunli, K., Cervone, G., Kafatos, M., & Taylor, P. (2007). Outgoing long wave radiation variability from IR satellite data prior to major earthquakes. *Tectonophysics*, *431*(1-4), 211-220.

Ouzounov, D., Pulinets, S., Hattori, K., & Taylor, P. (2018). *Pre-earthquake processes: A multidisciplinary approach to earthquake prediction studies* (Vol. 234). John Wiley & Sons.

Piroddi, L., Ranieri, G., Freund, F., & Trogu, A. (2014). Geology, tectonics and topography underlined by L'Aquila earthquake TIR precursors. *Geophysical Journal International*, *197*(3), 1532-1536.

Piscini, A., De Santis, A., Marchetti, D., & Cianchini, G. (2017). A Multi-parametric climatological approach to study the 2016 Amatrice–Norcia (Central Italy) earthquake preparatory phase. *Pure and Applied Geophysics*, *174*(10), 3673-3688.

Piscini, A., Marchetti, D., & De Santis, A. (2019). Multi-parametric climatological analysis associated with global significant volcanic eruptions during 2002–2017. *Pure and Applied Geophysics*, *176*(8), 3629-3647.

Pulinets, S. A., Legen'Ka, A. D., Gaivoronskaya, T. V., & Depuev, V. K. (2003). Main phenomenological features of ionospheric precursors of strong earthquakes. *journal of atmospheric and solar-terrestrial physics*, *65*(16-18), 1337-1347.

Pulinets, S., & Ouzounov, D. (2011). Lithosphere–Atmosphere–Ionosphere Coupling (LAIC)

model–An unified concept for earthquake precursors validation. *Journal of Asian Earth Sciences*, *41*(4-5), 371-382.

Qiang, Z. J., Xu, X. D., & Dian, C. G. (1991). Thermal infrared anomaly precursor of impending earthquakes. Chinese Science Bulletin, 36, 319–323.

Qin, K., Guo, G., & Wu, L. (2009). Surface latent heat flux anomalies preceding inland earthquakes in China. *Earthquake Science*, *22*(5), 555-562.

Qin, K., Wu, L. X., De Santis, A., Meng, J., Ma, W. Y., & Cianchini, G. (2012). Quasi-synchronous multi-parameter anomalies associated with the 2010–2011 New Zealand earthquake sequence. *Natural Hazards and Earth System Sciences*, *12*(4), 1059-1072.

Rapoport, Y., Grimalsky, V., Krankowski, A., Pulinets, S., Fedorenko, A., & Petrishchevskii, S. (2020). Algorithm for modeling electromagnetic channel of seismo-ionospheric coupling (SIC) and the variations in the electron concentration. *Acta Geophysica*, *68*(1), 253-278.

Rodger, C. J., Clilverd, M. A., & Thomson, N. R. (1999). Modeling of subionospheric VLF signal perturbations associated with earthquakes. *Radio Science*, *34*(5), 1177-1185.

Saraf, A. K., & Choudhury, S. (2005). Cover: Satellite detects surface thermal anomalies associated with the Algerian earthquakes of May 2003. *International Journal of Remote Sensing*, *26*(13), 2705-2713.

Scholz, C. H., Sykes, L. R., & Aggarwal, Y. P. (1973). Earthquake Prediction: A Physical Basis: Rock dilatancy and water diffusion may explain a large class of phenomena precursory to earthquakes. *Science*, *181*(4102), 803-810.

Scholz, C. H. (2002). Earthquakes and faulting.

Singh, R. P., Sahoo, A. K., Bhoi, S., Kumar, M. G., & Bhuiyan, C. (2001). Ground deformation of the Gujarat earthquake of 26 January 2001. *Journal of Geological Society of India (Online archive from Vol 1 to Vol 78)*, *58*(3), 209-214.

Singh, R. P., Bhoi, S., Sahoo, A. K., Raj, U., & Ravindranath, S. (2001). Surface

manifestations after the Gujarat earthquake. *Current Science*, *81*(2), 164-166.

Singh, R. P., Bhoi, S., & Sahoo, A. K. (2001). Significant changes in ocean parameters after the Gujarat earthquake. *Current Science*, *80*(11), 1376-1377.

Singh, R. P., Bhoi, S., & Sahoo, A. K. (2002). Changes observed in land and ocean after Gujarat earthquake of 26 January 2001 using IRS data. *International Journal of Remote Sensing*, *23*(16), 3123-3128.

Shearer, P. M. (2019). *Introduction to seismology*. Cambridge university press.

Sorokin, V. M., Chmyrev, V. M., & Hayakawa, M. (2020). A review on electrodynamic influence of atmospheric processes to the ionosphere. *Open Journal of Earthquake Research*, *9*(2), 113-141.

Tanimoto, T. (2007). Interaction of solid Earth, atmosphere, and ionosphere. *Treatise on geophysics*, *4*, 421-444.

Tariq, M. A., Shah, M., Hernández-Pajares, M., & Iqbal, T. (2019). Pre-earthquake ionospheric anomalies before three major earthquakes by GPS-TEC and GIM-TEC data during 2015–2017. *Advances in Space Research*, *63*(7), 2088-2099.

Tinti, E., Scognamiglio, L., Michelini, A., & Cocco, M. (2016). Slip heterogeneity and directivity of the ML 6.0, 2016, Amatrice earthquake estimated with rapid finite-fault inversion. *Geophysical Research Letters*, *43*(20), 10-745.

Tramutoli, V., Di Bello, G., Pergola, N., & Piscitelli, S. (2001). Robust satellite techniques for remote sensing of seismically active areas.

Tramutoli, V., Cuomo, V., Filizzola, C., Pergola, N., & Pietrapertosa, C. (2005). Assessing the potential of thermal infrared satellite surveys for monitoring seismically active areas: The case of Kocaeli (Izmit) earthquake, August 17, 1999. *Remote Sensing of Environment*, *96*(3-4), 409-426.

Tronin, A. A. (2000). Thermal IR satellite sensor data application for earthquake research in

China. *International Journal of Remote Sensing*, *21*(16), 3169-3177.

Tronin, A. A., Hayakawa, M., & Molchanov, O. A. (2002). Thermal IR satellite data application for earthquake research in Japan and China. *Journal of Geodynamics*, *33*(4-5), 519-534.

Tronin, A. A. (2002). Atmosphere-lithosphere coupling. Thermal anomalies on the Earth surface in seismic processes. *Seismo Electromagnetics: Lithosphere-Atmosphere-Ionosphere Coupling*.

Turcotte, D. L. (1991). Earthquake prediction. *Annual review of earth and planetary sciences*, *19*(1), 263-281.

Šprlák, M., Han, S. C., & Featherstone, W. E. (2020). Integral inversion of GRAIL inter-satellite gravitational accelerations for regional recovery of the lunar gravitational field. *Advances in Space Research*, *65*(1), 630-649.

Uyeda, S., Nagao, T., Hattori, K., Hayakawa, M., Miyaki, K., Molchanov, O., ... & Belyaev, G. (2001). Geophysical Observatory in Kamchatka region for monitoring of phenomena connected with seismic activity. *Natural Hazards and Earth System Sciences*, *1*(1/2), 3-7.

Uyeda, S., Nagao, T., & Kamogawa, M. (2009). Short-term earthquake prediction: Current status of seismo-electromagnetics. *Tectonophysics*, *470*(3-4), 205-213.

Varotsos, P. (1981). Seismic electric currents. *Prakt. Akad. Athenon*, *56*, 277-286.

Warwick, J. W., Stoker, C., & Meyer, T. R. (1982). Radio emission associated with rock fracture: possible application to the great Chilean earthquake of May 22, 1960. *Journal of Geophysical Research: Solid Earth*, *87*(B4), 2851-2859.

Wu, L., Zheng, S., De Santis, A., Qin, K., Di Mauro, R., Liu, S., & Rainone, M. L. (2016). Geosphere coupling and hydrothermal anomalies before the 2009 M w 6.3 L'Aquila earthquake in Italy. *Natural Hazards and Earth System Sciences*, *16*(8), 1859-1880.

Zhang, W., Zhao, J., Wang, W., Ren, H., Chen, L., & Yan, G. (2013). A preliminary

evaluation of surface latent heat flux as an earthquake precursor. *Natural Hazards and Earth System Sciences*, *13*(10), 2639-2647.

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